UV spectral irradiance responsivity calibrations using a scanning method in a monochromator-based facility

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The use of the NIST monochromator-based facility for irradiance responsivity calibration of filter radiometers from 300 nm to 1800 nm is described. Spectral irradiance responsivities are determined using a combination of the measured spectral power responsivity and the effective aperture areas. The effective aperture area is measured using a focussed output beam which is raster-scanned over a grid which overfills the aperture diameter of the filter radiometer. We show that if a uniform irradiance field is projected at the plane of the filter radiometer, then the exact aperture area of the filter radiometer need not be determined. We also show that irradiance responsivities can be measured using a variable-sized, rectangular output beam which is larger than the aperture diameter. Total uncertainties of 0.4 % (*k*=2) have been achieved in spectral irradiance responsivity measurements of < 1 mm diameter UV filter radiometers.

INTRODUCTION

Although National Measurement Institutes (NMI) routinely issue spectral power responsivity calibrations, there are often requests for spectral irradiance responsivity calibrations of detectors and filter radiometers [1]. The knowledge of the incident irradiance or the optical power incident on a surface area is a much more relevant quantity in the areas of ultra-violet (UV) disinfection or materials curing. In the past, irradiance responsivities were determined using a two-step, source-based approach, where the relative or absolute power responsivities were calibrated and then referenced to a calibrated detector using a uniform UV source.

We describe the process and uncertainties of UV spectral irradiance responsivity calibrations using the NIST Visible Spectral Calibration Facility (VisSCF) [2]. The VisSCF is a monochromator-based facility with precision, calibrated x- and y-scanning stages which has been configured to measure spatial uniformities and effective aperture areas along with providing spectral power responsivity calibrations. The advantages of using a well characterized spectral power responsivity calibration setup for spectral irradiance responsivity calibration are many. Most of the instrument characterizations and uncertainty analysis will have been already performed in setting up a power responsivity calibration facility. Also, the spatial-scanning method has been extensively used by NMIs for measurements of aperture area primarily using scanned laser beams [3]. Here we show that this method can be used to measure UV spectral irradiance responsivities of small < 1 mm diameter filter radiometer with low additional uncertainties even when the size of the output beam is larger than the area of the filter radiometer.

EXPERIMENTAL SETUP

A calibrated spectral irradiance responsivity of a 365 nm UV filter radiometer is shown in Fig. 1. The UV filter radiometer is aligned into detector positions and first measured for initially for effective spectral power responsivity by comparisons to NIST working standard Si diodes.

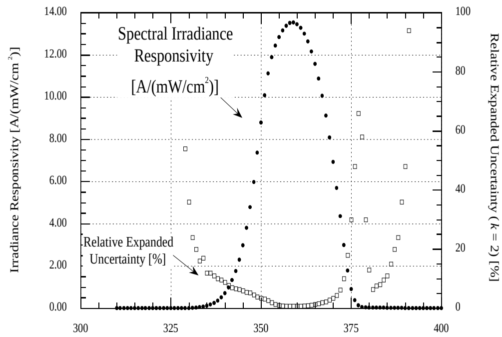

Figure 1. The irradiance responsivity of a ~ 1 mm diameter UV filter radiometer which is centered at 365 nm.

Since the optical beam can be larger than the opening of the filter radiometer, this measurement mode does not determine the correct spectral power responsivities. The rectangular optical output beam from the monochromator is shaped in the horizontal direction using variable-width slits on the monochromator and the height is adjusted using independently adjustable vertical slits. This separation of the two axes are to preserve the wavelength calibration as the optical beam size is changed. For the measurements shown in Fig. 1 a 1.0 mm by 1.0 mm square optical beam was used.

After the effective spectral power responsivities are measured, the UV filter photometers are also scanned to determine the effective aperture area at the peak of the spectral responsivity. A plot of the spatial power responsivity scan is shown in Fig. 2. The plot is

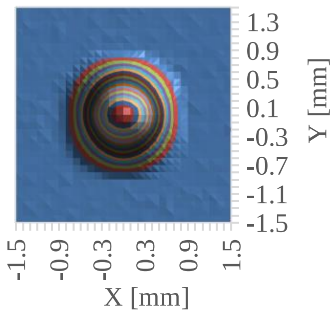

Figure 2. Spatial mapping of the 365 nm filter radiometer with a 1 mm diameter opening using a 0.85 mm square optical beam. The spatial contours show the convolved shape.

normalized to the center and the effective area is determined using,

$$A_{eff} = \Delta x\, \Delta y \sum_{j=n_x}^{n_x} \sum_{k=n_y}^{n_y} \frac{\Phi_{j,k}}{\Phi_L}, \qquad (1)$$

where Δx and Δy are the horizontal and vertical step sizes of the measurements and the double summation denotes a total sum of the normalized intensities [3]. The determined effective areas for the same filter radiometer can vary greatly depending on the optical beam size as shown in Fig. 3.

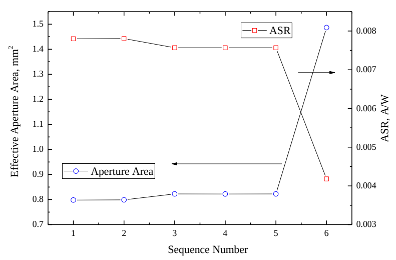

Figure 3. Effective aperture areas and ASR measured using different optical output beam sizes.

The irradiance responsivities in Fig. 4 are determined using the product of the effective area and the effective ASR,

$$S_E = A_{eff} * ASR_{eff}, \qquad (2)$$

where S_E is the spectral irradiance responsivity.

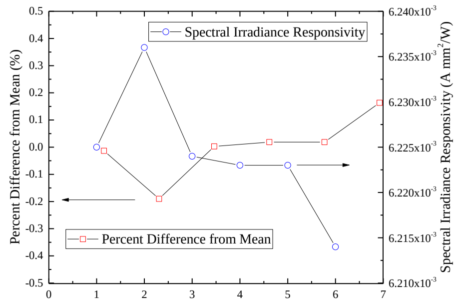

Figure 4. Spectral irradiance responsivities of the 435 nm filter radiometer measured using different optical beam sizes. The large variations in Fig. 3 collapses to variations of only 0.2 % in irradiance responsivities.

The total uncertainties of the measurements shown in Fig. 4 are about 0.45 % (k=2) at 435 nm.

CONCLUSIONS

We demonstrate that monochromator-based facilities designed for spectral power responsivity calibrations can be adopted for irradiance responsivity calibrations of UV filter radiometers with resulting uncertainties of 0.45 % (k=2). This has been achieved by scanning optical beams which can vary in sizes and which can be larger than the detector aperture areas. These different irradiance responsivities are within the combined uncertainties of the measurements. This scanning approach can be easier and faster in practice than the traditional two-step method currently utilized at NMIs while achieving lower uncertainties that the presently utilized methods.

REFERENCES

1. D R Taubert, R Friedrich, J Hartmann and J Hollandt, "Improved calibration of the spectral responsivity of interference filter radiometers in the visible and near infrared spectral range at PTB," Metrologia, **40**, 2003.
2. T. C. Larason and J. M. Houston, "Spectroradiometric Detector Measurements: Ultraviolet, Visible, and Near-Infrared Detectors for Spectral Power," NIST Special Publication 250-41 (2008).
3. E. Ikonen, P. Toivanen, A. Lassila, "A new optical method of high-accuracy determination of aperture area," Metrologia, **35**, 1998.